*An Automatic Mosaicking System**‡

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I. INTRODUCTION

THE increasing demand upon the science of mapping for accurate high-speed data reduction has been instrumental in developing demands for rapid and accurate map positions. Such coordinate positions and map detail can be supplied by a controlled gridded photomosaic. Preparing photomosaics, normally a cut and paste process, saves time over the laborious drafting of a topographic map. If the repetitive processes involved in cutting and pasting a photomosaic are eliminated, and the successive series of rectified photo images are placed in their true relative position on a single film negative, then there can be achieved significant economies of time and labor.

The requirement for hardware which will produce a gridded controlled photomosaic from known *X*-tilt, *Y*-tilt, nadir-point positions, and photo-azimuths was received by the U. S. Engineer Geodesy, Intelligence and Mapping Research and Development Agency (GIMRADA) in January 1959. Physical limitations were that the instrument or system be contained in an area 80×120 inches by 72 inches high. The system was required to be capable of accepting aerial photography taken with a six-inch focal-length mapping camera from ranges of 10,000 to 50,000 feet, at tilts of 0 to 10 degrees and produce a standard scale gridded photomosaic, 24×24 inches.

II. CONCEPT

Preliminary studies were made at GIMRADA; a purchase description was prepared and was distributed to qualified contractors. Several proposals were received and evaluated with regard to the time required for development and the cost to the Government. A research and development contract for the design and fabrication of an automatic mosaicker was awarded to the Union Instrument Corporation, Plainfield, New Jersey, in April 1959.

The original concept was of a single instrument which would accept aerial photography and known orientation data, would rectify to the known datum, and would successively position the exposures on a single sheet of photo sensitive material, thus producing a photomosaic. During the five month study period devoted to extensive research into rectifiers and positioning equipment, the contractor determined that the single instrument concept was not feasible in the present state-of-the-art because of the required 1.0× to 0.2× magnification and height limitation of 72 inches. A two-stage system was proposed in which rectification, some magnification and nadir point location was accomplished, and final magnification and positioning was completed in the second stage. This solution was deemed acceptable. It was also deduced that a two-stage system could speed the completion of the mosaic, as rectification and film positive

* Presented at the 28th Annual Meeting of the Society, The Shoreham Hotel, Washington, D. C., March 14–17, 1962.
‡ The Abstract is on page 348 of the 1962 YEARBOOK.

processing procedures could be carried out simultaneously on some flights while the positioning instrument was mosaicking previous flights.

As presently conceived and under development, the Automatic Mosaicking System consists of two units: an automated autofocusing rectifier and an automated variable magnification positioning printer (see Figure I). Each unit is equipped with an individual electronic control console capable of conversion to punched tape operation, yet retaining a manual operational capability in the event of servo motor failure. Both units operate from 115 volt, 60 cycle circuits. Neither unit exceeds 72 inches in height, and the entire system can be contained in a floor area of 80×120 inches.

III. Automatic Autofocusing Rectifier

In developing the first-stage instrument, the contractor modified a Zeiss SEG V Autofocusing Rectifier to the desired requirements (see Figure II). A vacuum backed transport easel which accepted $9\frac{1}{2}\times9\frac{1}{2}$ inch roll film was designed to replace the conventional flat easel. The vacuum operates through grooved lines, two of which interesect at the center directly beneath the principal point of the negative stage. An electronic control console was also designed which translates X-tilt and Y-tilt data, introduced as tangent angles, through a servo amplifier to servo motors which tilt the negative stage and transport easel to the required angle (see Figure III).

The SEG V autofocus rectifier contains a small computer in its base which automatically computes the X and Y displacements of the principal point with reference to the tilt angles; as the easel and negative stages are tilted according to the following formula:

$$\Delta X = \frac{fe}{2}\left(\frac{fa^2}{fe^2} - 1 \text{ plus } \frac{1}{v^2}\right) TgB$$

in which:

ΔX = the displacement of X or Y in millimeters

fa = the focal-length of the taking camera (153 mm.)

fe = the rectifier focal-length (180 mm.)

V = the magnification setting of the instrument

B = the easel tilt setting in the direction of the component (a tangent value taken from tables)

During studies of this instrument, it was noted that for a combination of 153 mm. taking camera focal-length and 180 mm. rectifier focal-length, a particular magnification, approximately 0.760× physically located the nadir point on a plumb line through the optical axis. Applying the above formula to tilts up to 10 degrees, the variation in magnification was so small, i.e., at 3 degrees, 0.759×; at 5 degrees, 0.762×; at 7 degrees,

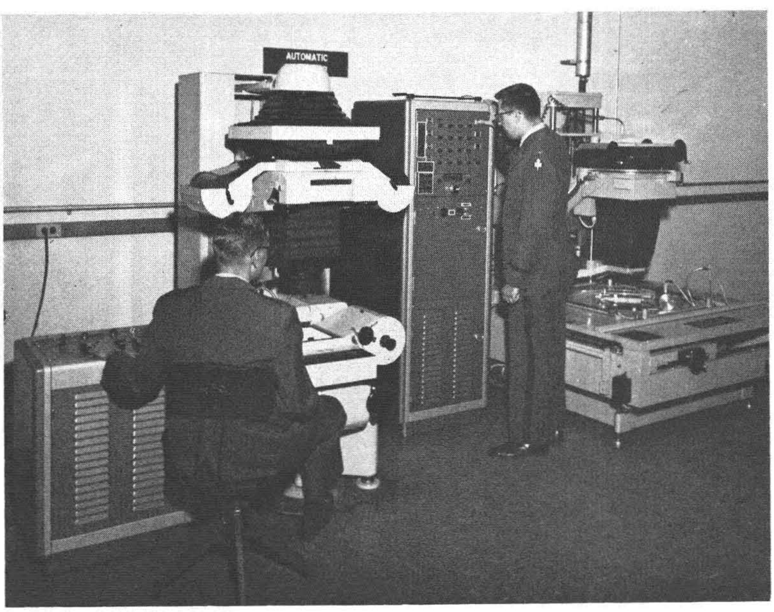

Fig. I. Automatic mosaicking system in operation.

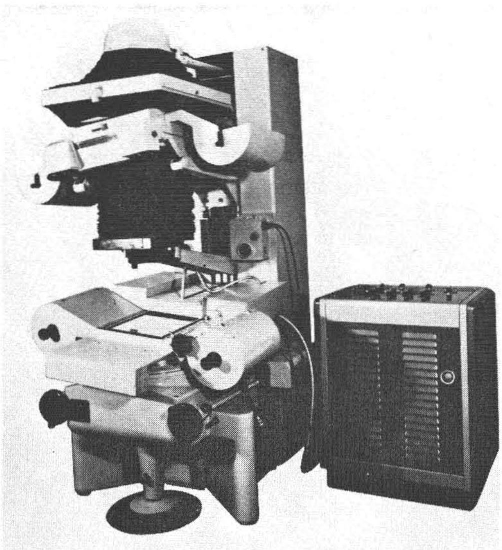

FIG. II. Automatic autofocus rectifier and electronic control console.

0.763X and 10 degrees, 0.764×, that this value could be accepted for the rectification procedure. The magnification was fixed on the rectifier to 0.761× to accommodate the majority of tilted photography which might be used.

Since the nadir point was located physically in a line with the optical axis, and the transport easel tilted about a ball joint, printing out the nadir point could be accomplished by the use of illuminated fiducial marks placed at the ends of the intersecting lines on the transport easel. The illumination was to be supplied by cutting windows in the vacuum easel of the transport and placing pilot lamps in the housing of the ball joint (see Figure IV).

A white painted cover slide on the transport easel enables the operator to examine the projected image during orientation of the negatives. An automatic timer is wired to the control console.

After manual orientation of the selected negative and setting of a predetermined exposure on the timer, the X-tilt and Y-tilt tangent equivalents are placed on the decade panel of the control console. The camera focal-length for the film roll has been preset and the magnification is fixed. X and Y buttons are depressed on the console; instantaneously, the servo motors drive the negative stage and transport easel to the required tilt angles. The computer in the base of the rectifier computes the X and Y displacements of the negative stage and actuates motors which shift the negative stage. Seventeen seconds from initiation, the cover slide of the transport easel moves back and trips a micro-switch which automatically removes the red filter from the lens; the exposure is then made. Simultaneously, the new fiducial-marks are exposed from beneath the easel. Upon completion of the exposure, the red filter slides back, and the cover slide returns to its original position, tripping another micro-switch which actuates the wind mechanism of the film transport. This releases the vacuum, and the film advances $9\frac{1}{2}$ inches to the next unexposed area.

Upon completion of the desired film positives, they are removed and processed for use in the second stage.

IV. Variable Magnification Positioning Printer

In designing the second-stage instrument, the variable magnification positioning printer, the requirements were that orientation in the mosaic would be provided by the grid coordinates of the nadir point, plus the azimuth of the aerial photograph. Thus, no tilting was required, merely X, Y and Z positioning and rotational motion (see Figure V). GIMRADA requirements were that any part of any photo-

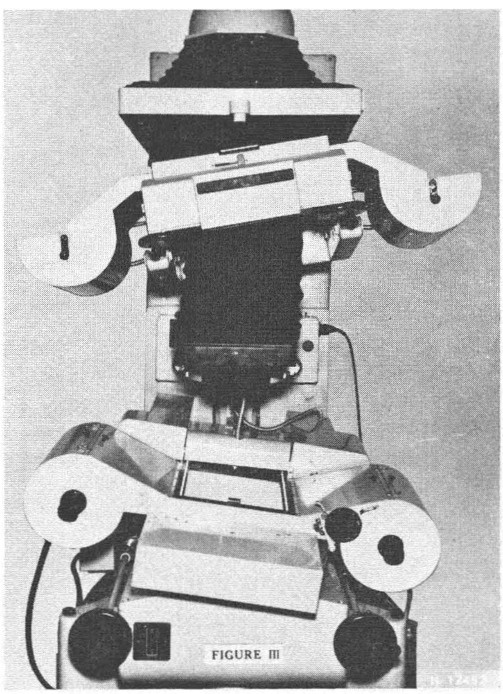

FIG. III. Automatic autofocus rectifier in operation.

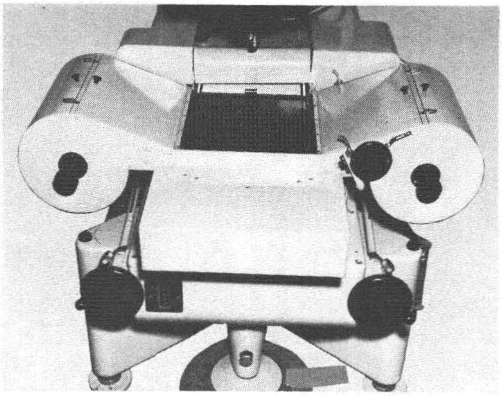

FIG. IV. Transport easel of automatic autofocus rectifier with cover slide open.

graph used could be used in producing the mosaic; therefore, the frame holding the easel had to be more than twice the size of the 24×24 inch easel. Film clips mounted on the vacuum easel were designed to hold the photographic sheet film in place. Autofocusing was maintained by using a cam inversor connected by sprocket chains to the negative stage and lens. Servo-motors were placed to rotate the negative stage and the mask on command. Automatic dodging capability was designed by adapting the infrared quenching type contrast control. The requirement for 10,000 to 50,000 foot flight-height photography required magnifications of 1.31× to 0.25× in the second stage. Besides having a manual capability, all motions were to be controlled from the electronic control console.

A considerable amount of experimental work and back-tracking was performed in the construction of the second-stage. Among the problems encountered was that the shape of the photographic image changes as the photograph is tilted. Images other than rectangles are difficult to position; therefore, it was decided to use the maximum rectangle permissible for each tilted photograph. Then as the magnification decreased, the size of the mask opening must decrease; this was to be performed automatically.

On the control console decade panel (see Figure VI) the first row of knobs is used to introduce the X coordinate in millimeters; the second row, the Y coordinate; the third row, the Z coordinate; the fourth row, the aximuth of the photograph in degrees. A potentiometer was added to the panel which ratios the size of the mask opening to the resultant tilt angle. An automatic timer is also mounted on the panel.

Manual capability is retained for operating the X-motion, Y-motion and Z-motion by means of handwheels and scales on which increments may be observed. A scale fixed to the negative stage swing motion enables azimuth settings to be made manually.

In operation, the vacuum easel is slid out of the easel frame on a rack placed on the left

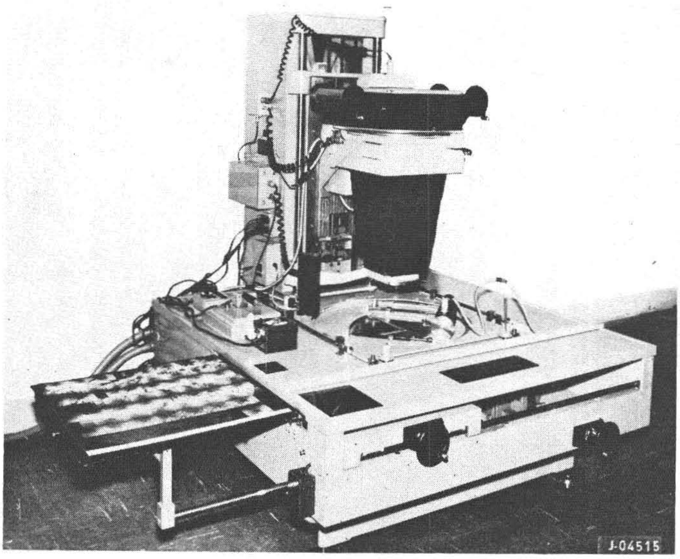

FIG. V. Variable magnification positioning printer. Easel in loading position with a processed mosaic in place.

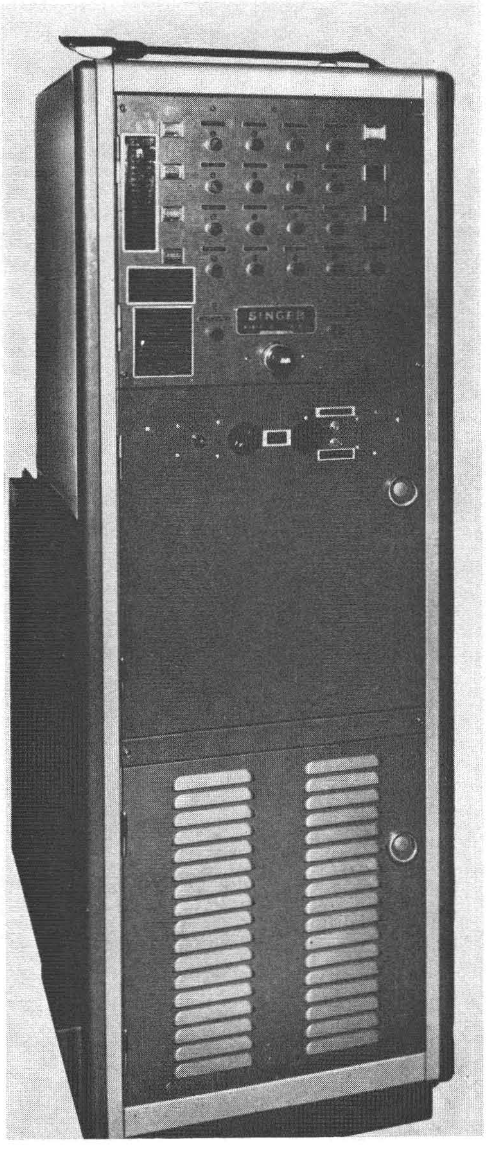

FIG. VI. Electronic control console for positioning printer. Rack on left contains glass grid.

side, (see Figure V) a sheet of photographic film is positioned, a glass grid is registered on the easel and exposed with a hand lamp. After removal of the glass grid, an overlay sheet of Diazo is placed on top of the photographic film. The easel is slid back into position, and the desired photograph selected at the negative stage. Orientation of the nadir point fiducial marks is made to the stage plate manually. X-coordinate, Y-coordinate, Z-coordinate and azimuth are introduced on the decade panel. An exposure time is set and the actuating buttons depressed.

The vacuum easel then slides to its correct X and Y position. The negative stage and mask automatically swing to the required azimuth. Autofocusing is maintained by the negative stage and lens as they move in Z to attain the required flight-height. All motions are operated by servo motors through amplified signals received from the control console. After the exposure is made, a chemical pad is passed over the mask opening. This blackens the Diazo overlay sheet thus preventing overlapping of the next exposure. This procedure is repeated for each exposure until the mosaic is completed. Provision is also made for printing marginal information.

V. SUMMARY

The Automatic Mosaicking System is designed to produce a standard scale gridded, controlled photomosaic from a series of aerial photographic negatives exposed in a six-inch focal-length mapping camera. Rectification procedures depend upon known orientation elements including X-tilt and Y-tilt angles in the first stage. Assembling the mosaic depends upon known grid coordinates of the nadir point, magnification and azimuth of each aerial photograph in the second stage. Devlopment has proceeded to the point where the first-stage is operational barring minor adjustments; the second stage needs adjustment and calibration.

Storm Damage Surveys

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THE slow-moving extra-tropical storm along the East Coast of the United States on March 6–9, 1962, was one of the most severe storms in recent history. The resulting damage as reported at a Congressional hearing was approximately 192 million dollars. The storm caused 32 deaths and extensive changes to the coast line from the Carolinas to Cape Cod, Mass. Damage was experienced as far south as Florida and the storm was felt as far north as the Coast of Maine. It will require the entire summer for the U. S. Coast